In-situ TEM Studies of Thin Film Oxide Heterostructures

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(1) Motivation

- Carry out high spatial resolution imaging of magnetic and ferroelectric domains together with their dynamics, using Lorentz TEM (LTEM) and electron holography.
- Correlate transport data DIRECTLY with microstructure via in-situ TEM experiments, for example the tunneling characteristics across magnetic tunnel junction barriers or gate oxide films
- This will lead to an enhanced understanding of the fundamental properties of nano-scale magnetic and ferroelectric structures with applications in memory, spintronics and MEMS devices

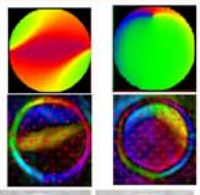
(2) Major Accomplishments

Domain imaging using Lorentz TEM

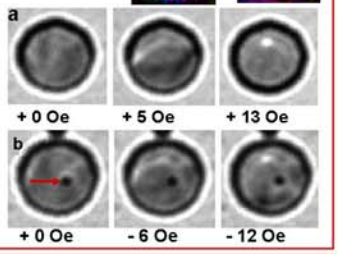
Magnetization reversal in a circular NiFe element: Defect results in formation of two magnetic vortices of opposite chirality

micromagnetic simulation

reconstructed phase image



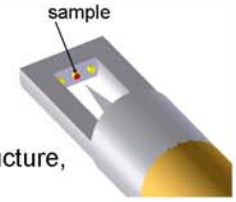
a) as-deposited and b) after FIB milling an induced defect (arrowed)

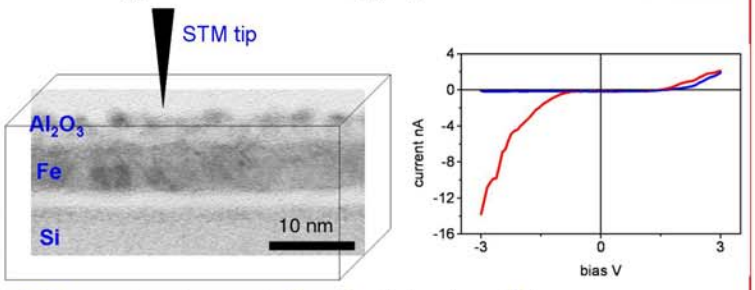


* Collaboration between University of Oxford (AKPL and A. Kohn) and Hewlett-Packard (T. Anthony) [Ref 1]

Transport and nano-biasing holder

Novel nano-biasing holder:
- Collaboration w/ Hummingbird Scientific (delivery March 2006)
- Enable simultaneous analysis of microstructure, chemistry, and local tunneling properties





STM experiment on a similar sheet structure: I-V curves across a 1.4 nm thick Al_2O_3 barrier on a 5 nm Fe electrode on (red) and off (blue) Au nanocrystals in the alumina

* Collaboration between Univ of Oxford (AKPL and J.P. Barnes) and MPI, Halle (W. Wulfhekel)

(3)Impact

Short-term:

- Understanding the impact of the local chemical, magnetic and spatial environment on properties via DIRECT correlation between microstructure and local transport properties
- Interactions of domain walls with interfaces and grain boundaries to be elucidated without removing electrode layers

Long-term:

- Design of novel devices based on oxide heterostructures

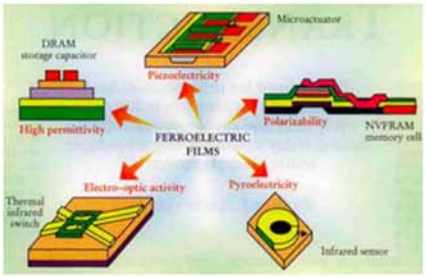


Image courtesy of O. Auciello (ANL-MSD)

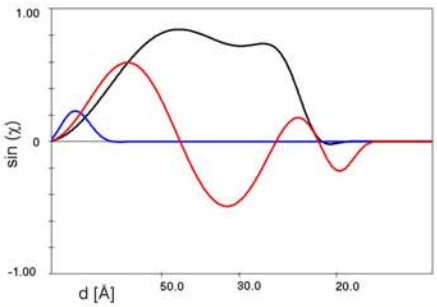
(4) Future Directions

In-situ TEM analysis of domain dynamics and transport properties in novel thin film heterostructures:

- Interactions between elements in arrays of layered magnetic nanostructures (collaboration with S. Bader, ANL-MSD)
- Magnetic tunnel junctions and spin-injectors (half-metallic electrodes)
- Current-confined path GMR structures
- Interaction of domain walls with FIB-patterned defects in novel systems
- Ferroelectric nanocapacitors
- High-k dielectric layers for gate oxide structures

Novel science will involve developing novel instrumentation:

- Magnetizing holder for in-situ application of magnetic fields with variable temperature capability (collaboration with EMC)
- Dedicated Lorentz TEM instrument with aberration correction (collaboration with EMC; white paper submitted to BES)
- Development of new techniques for extracting quantitative phase information from the Lorentz TEM images



Contrast transfer function for Lorentz lens showing inherent loss of resolution associated with magnetic imaging (blue curve)

black: Scherzer defocus
red: Focus of least confusion
blue: -30 μm defocus
(Lorentz imaging conditions)

A K Petford-Long. A Kohn, T Bromwich, V Jackson, F Castaño and L J Singh, Thin Solid Films (In Press: available on-line).

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